Deployment options for OSGi applications in the cloud/edge

Deployment options for OSGi applications in the cloud/edge

Speaker

Dirk Fauth
Research Engineer
Eclipse Committer

ETAS GmbH
Borsigstraße 24
70469 Stuttgart

dirk.fauth@etas.com
www.etas.com

https://vogella.com/blog/
Twitter: fipro78

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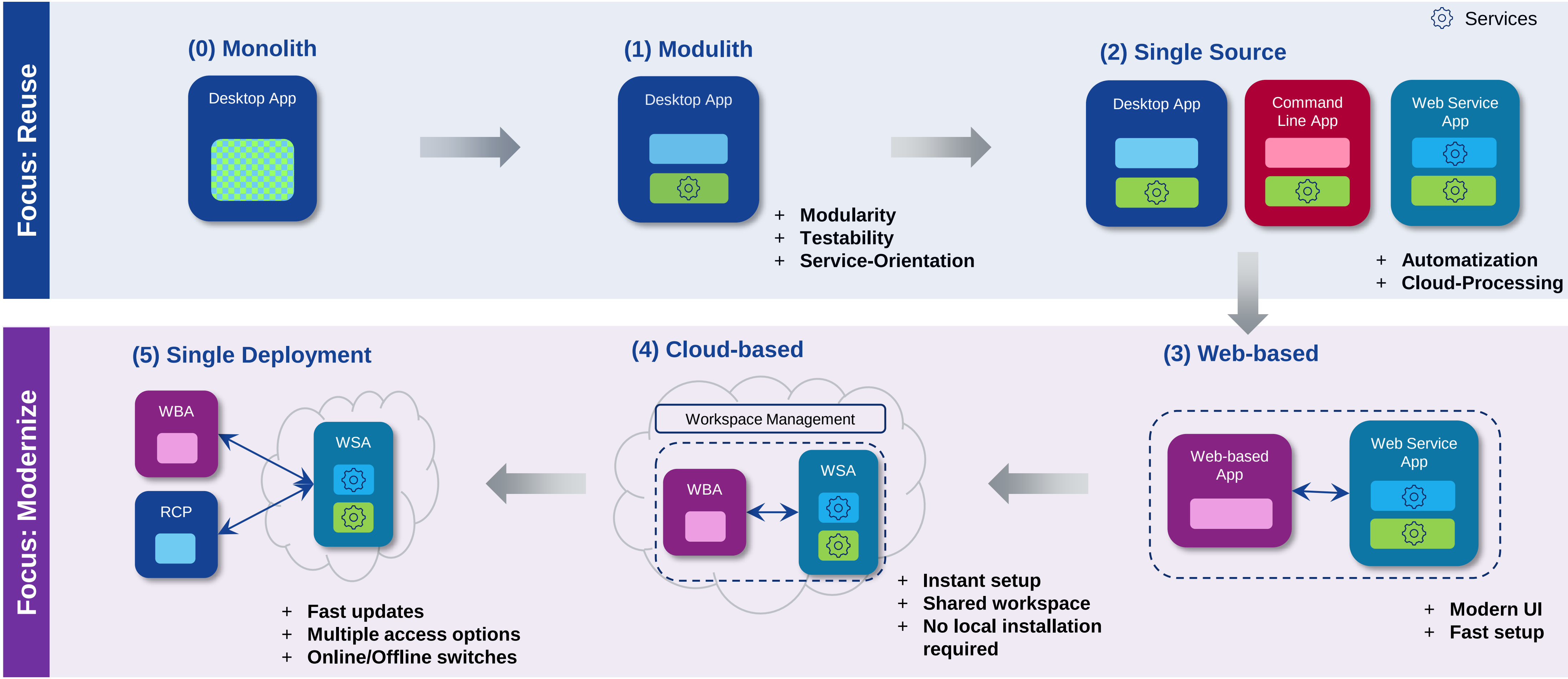
Deployment options for OSGi applications in the cloud/edge

Evolution Path

🟩 Business Logic
🟦 User Interface
⚙ Services



Focus: Reuse

(0) Monolith

(1) Modulith

- + Modularity
- + Testability
- + Service-Orientation

(2) Single Source

- + Automatization
- + Cloud-Processing

Focus: Modernize

(3) Web-based

- + Modern UI
- + Fast setup

(4) Cloud-based

- + Instant setup
- + Shared workspace
- + No local installation required

(5) Single Deployment

- + Fast updates
- + Multiple access options
- + Online/Offline switches

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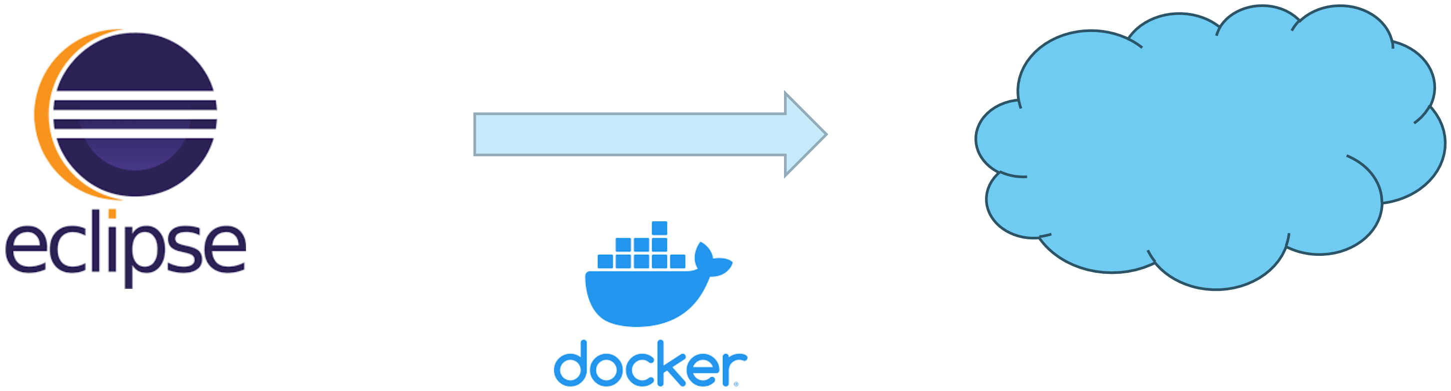
Deployment options for OSGi applications in the cloud/edge

Motivation

Shift existing Eclipse application (partly) to the cloud



„Startup of a Java application to slow for cloud applications!“

„Size of a container for a Java application to big!“

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Deployment options for OSGi applications in the cloud/edge

Overview

1. **Deployment Variants**
2. **Container**
3. **Benchmark**
4. **Conclusion**

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Deployment Variants

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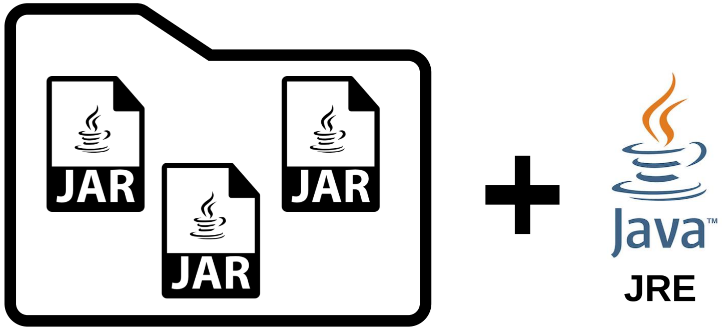
Deployment Variants

General



Multiple JARs in a folder

JAR
+
Java™
JRE

Executable JAR

Custom JRE (jlink)

Native Executable

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Deployment Variants

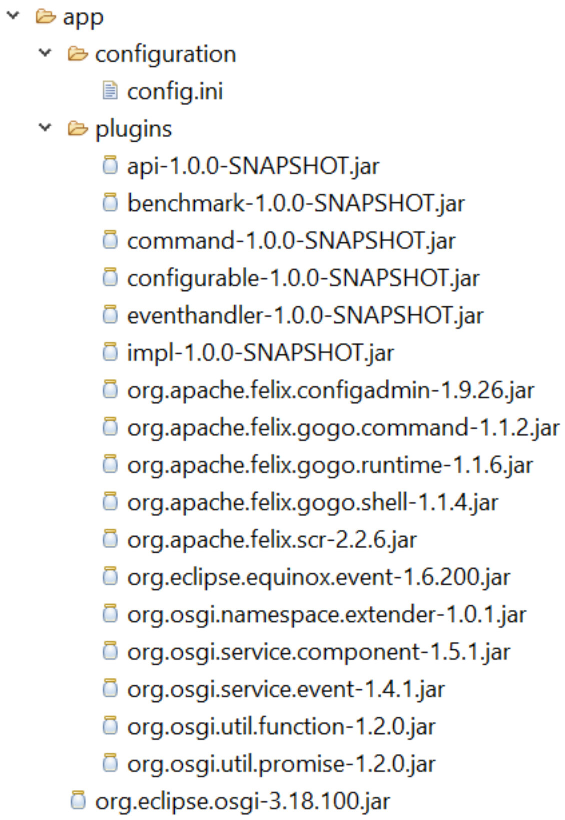
Multiple JARs in a folder

- Multiple JAR files (OSGi bundles) inside a folder
- Additional configuration file
- Launcher

```
org.eclipse.osgi
  :org.eclipse.core.runtime.adaptor.EclipseStarter
```

```
java -jar org.eclipse.osgi-3.18.100.jar
```

- Build
  - `maven-dependency-plugin`
  - `maven-resources-plugin`



```
app
  configuration
    config.ini
  plugins
    api-1.0.0-SNAPSHOT.jar
    benchmark-1.0.0-SNAPSHOT.jar
    command-1.0.0-SNAPSHOT.jar
    configurable-1.0.0-SNAPSHOT.jar
    eventhandler-1.0.0-SNAPSHOT.jar
    impl-1.0.0-SNAPSHOT.jar
    org.apache.felix.configadmin-1.9.26.jar
    org.apache.felix.gogo.command-1.1.2.jar
    org.apache.felix.gogo.runtime-1.1.6.jar
    org.apache.felix.gogo.shell-1.1.4.jar
    org.apache.felix.scr-2.2.6.jar
    org.eclipse.equinox.event-1.6.200.jar
    org.osgi.namespace.extender-1.0.1.jar
    org.osgi.service.component-1.5.1.jar
    org.osgi.service.event-1.4.1.jar
    org.osgi.util.function-1.2.0.jar
    org.osgi.util.promise-1.2.0.jar
  org.eclipse.osgi-3.18.100.jar
```

https://www.eclipse.org/equinox/documents/quickstart-framework.php

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Deployment Variants

Executable JAR

- Executable JAR that includes each required bundle as embedded JAR file
- Configuration also included in the executable JAR
- Launcher

  `aQute.launcher.pre.EmbeddedLauncher`

```
java -jar equinox-app.jar
```

- Build
  - `bnd-maven-plugin`
  - `bnd-export-maven-plugin`

https://bnd.bndtools.org/
https://bndtools.org/
https://github.com/bndtools/bnd/tree/master/maven-plugins

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Deployment Variants

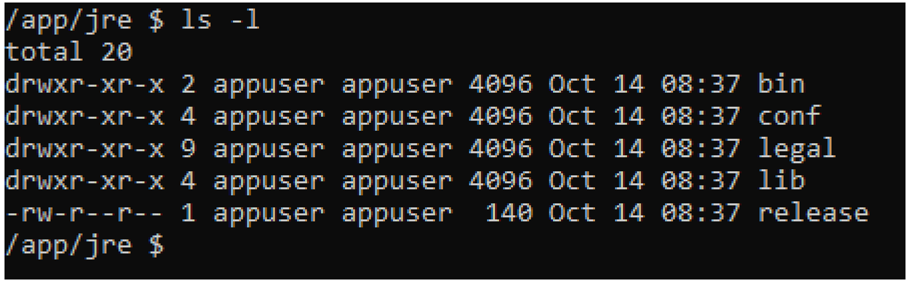
Custom JRE via jlink

- Create a custom JRE with `jlink` command of the JDK
  - *assemble and optimize a set of **modules** and their dependencies into a custom runtime image*

https://docs.oracle.com/en/java/javase/17/docs/specs/man/jlink.html

- Folder layout like JRE
- Launcher: `java` command

```
java [options] -m <module>[/<mainclass>]
```



```
/app/jre $ ls -l
total 20
drwxr-xr-x 2 appuser appuser 4096 Oct 14 08:37 bin
drwxr-xr-x 4 appuser appuser 4096 Oct 14 08:37 conf
drwxr-xr-x 9 appuser appuser 4096 Oct 14 08:37 legal
drwxr-xr-x 4 appuser appuser 4096 Oct 14 08:37 lib
-rw-r--r-- 1 appuser appuser  140 Oct 14 08:37 release
/app/jre $
```

- Issue with OSGi and jlink
  Most available OSGi bundles do not contain a `module-info.class`
  → **`automatic module cannot be used with jlink`**

JPMS

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Deployment Variants

Native Executable with GraalVM

- *Native Image is a technology to compile Java code ahead-of-time to a binary – a native executable. A native executable includes only the code required at run time, that is the application classes, standard-library classes, the language runtime, and statically-linked native code from the JDK.*

- Can be created using the GraalVM `native-image` tool
  - From a **Class**, a **JAR (classpath)** or a **Module (modulepath)**

- "Closed world assumption"
  → all the bytecode in your application that can be called at run time must be known at build time

- Issue with OSGi and `native-image`
  Dynamic classloading per bundle managed by OSGi Framework (Module Layer)
  `java.lang.NullPointerException: A null service reference is not allowed.`

https://www.graalvm.org/reference-manual/native-image/

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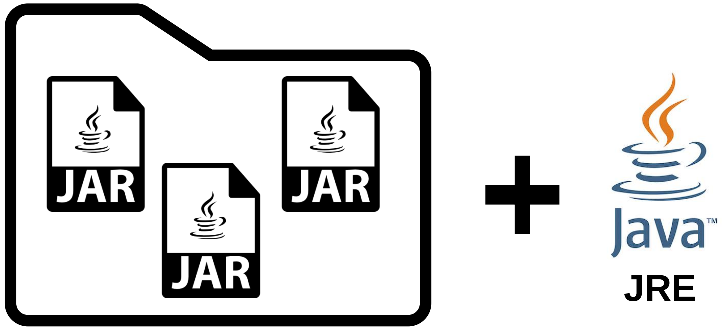
Deployment Variants

OSGi



Multiple JARs in a folder

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Deployment Variants

Custom JRE via jlink - OSGi

- Add `module-info.class`
  - ModiTect
    https://github.com/moditect/moditect
    → Intrusive change that adds an artifact to an existing published JAR
    OSS license compatibility?
    Checksum?
    → Requires knowledge on internals for generation
    Maintenance?
  - **Bndtools JPMS Support**
    https://bnd.bndtools.org/chapters/330-jpms.html

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Deployment Variants

Bndtools JPMS Support

Enable creation of `module-info.class` for each bundle, e.g. via `bnd-maven-plugin`

```
<plugin>
  <groupId>biz.aQute.bnd</groupId>
  <artifactId>bnd-maven-plugin</artifactId>
  <configuration>
    <bnd>
      <![CDATA[
Bundle-SymbolicName: ${project.groupId}.${project.artifactId}
-sources: true
-contract: *
-jpms-module-info:org.fipro.service.command;modules='org.apache.felix.configadmin'
-jpms-module-info-options: org.osgi.service.cm;ignore="true"
]]>
    </bnd>
  </configuration>
</plugin>
```

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Deployment Variants

Bndtools JPMS Support

Enable creation of `module-info.class` for **executable jar** via `.bndrun` file

```
-jpms-module-info: \
    ${project.groupId}.equinox.${project.artifactId};\
        version=${project.version};\
        ee=JavaSE-${java.specification.version}
-jpms-module-info-options: jdk.unsupported;static=false
```

This makes the executable jar itself a module!

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Deployment Variants

Custom JRE via jlink with Bndtools JPMS support

Build

```
$JAVA_HOME/bin/jlink \
    --add-modules org.fipro.service.equinox.app \
    --module-path equinox-app.jar \
    --no-header-files \
    --no-man-pages \
    --output /app/jre
```

Launch

```
/app/jre/bin/java \
  -m org.fipro.service.equinox.app/aQute.launcher.pre.EmbeddedLauncher
```

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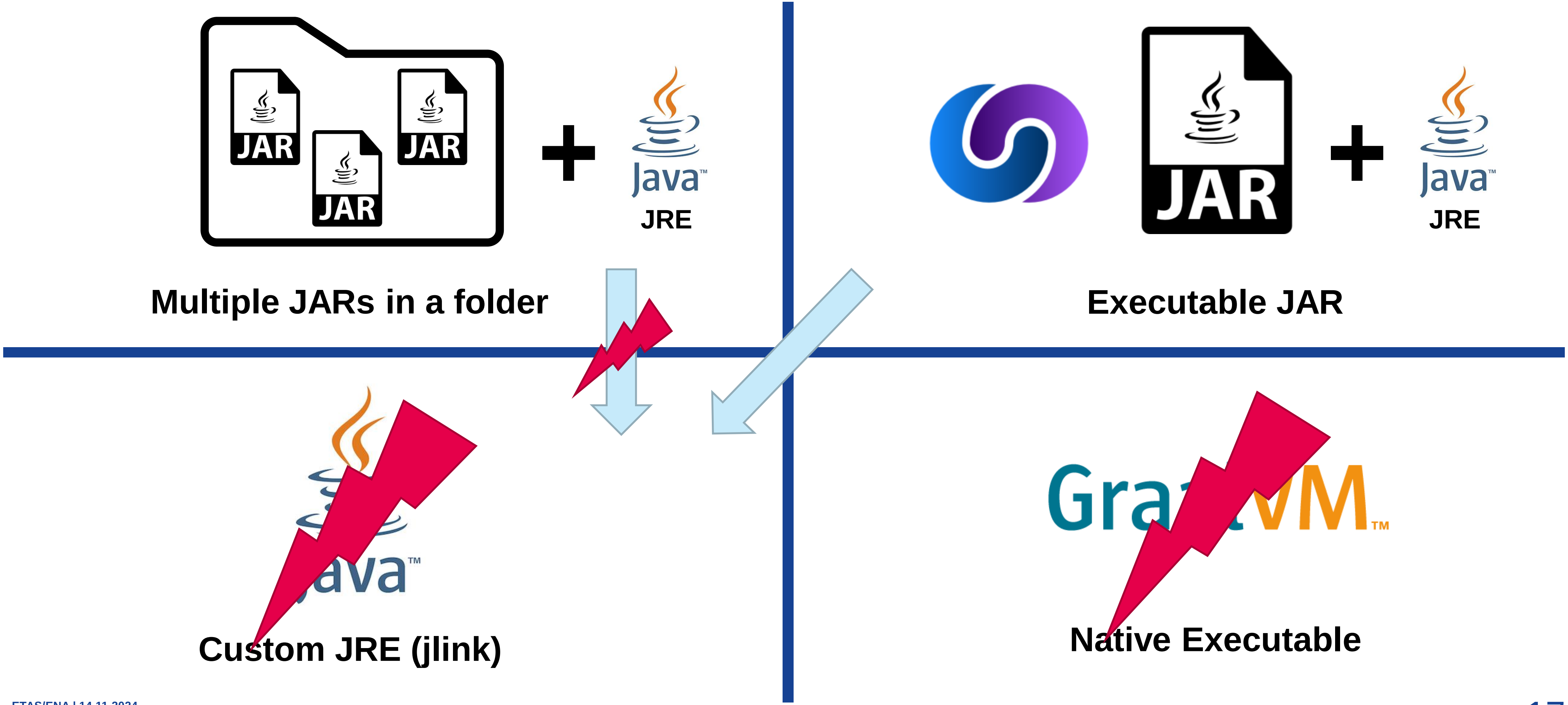
Deployment Variants

OSGi



Multiple JARs in a folder

Executable JAR

Custom JRE (jlink)

Native Executable

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Deployment Variants

OSGi Connect

- *OSGi Connect allows for bundles to exist and be installed into the OSGi Framework from the flat class path, the module path (Java Platform Module System), a jlink image, or a native image.*

  → Allows to start an OSGi application without the full OSGi Module Layer

OSGi Core R8 – Connect Specification
https://docs.osgi.org/specification/osgi.core/8.0.0/framework.connect.html

Apache Felix Atomos
https://github.com/apache/felix-atomos

Ubiquitous OSGi - Android, Graal Substrate, Java Modules, Flat Class Path
https://www.youtube.com/watch?v=KxmtzjHBumU

OSGi R8, Felix 7, Atomos and the future of OSGi@Eclipse
https://www.youtube.com/watch?v=oitFMbztf5s

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Deployment Variants

GraalVM Native Image with OSGi Connect

- **Preparation**
  1. Add/use Atomos to be able to start the OSGi application from the flat classpath
  2. Generate reachability metadata via tracing agent (reflection, resources, …)
  3. Update generated metadata
- **Build**
  - Via GraalVM build plugins (Maven/Gradle)
  - Docker multi-stage build using GraalVM container images
- **Notes/Remarks**
  - `native-image` build only worked with **flat classpath** and **listing all jars explicitly**
  - Build result is platform-dependent
  - `atomos_lib` folder or index file needed for Atomos to discover bundles and load bundle entries
  - Still not everything is working as expected (e.g. `scr:list` produces an empty output)

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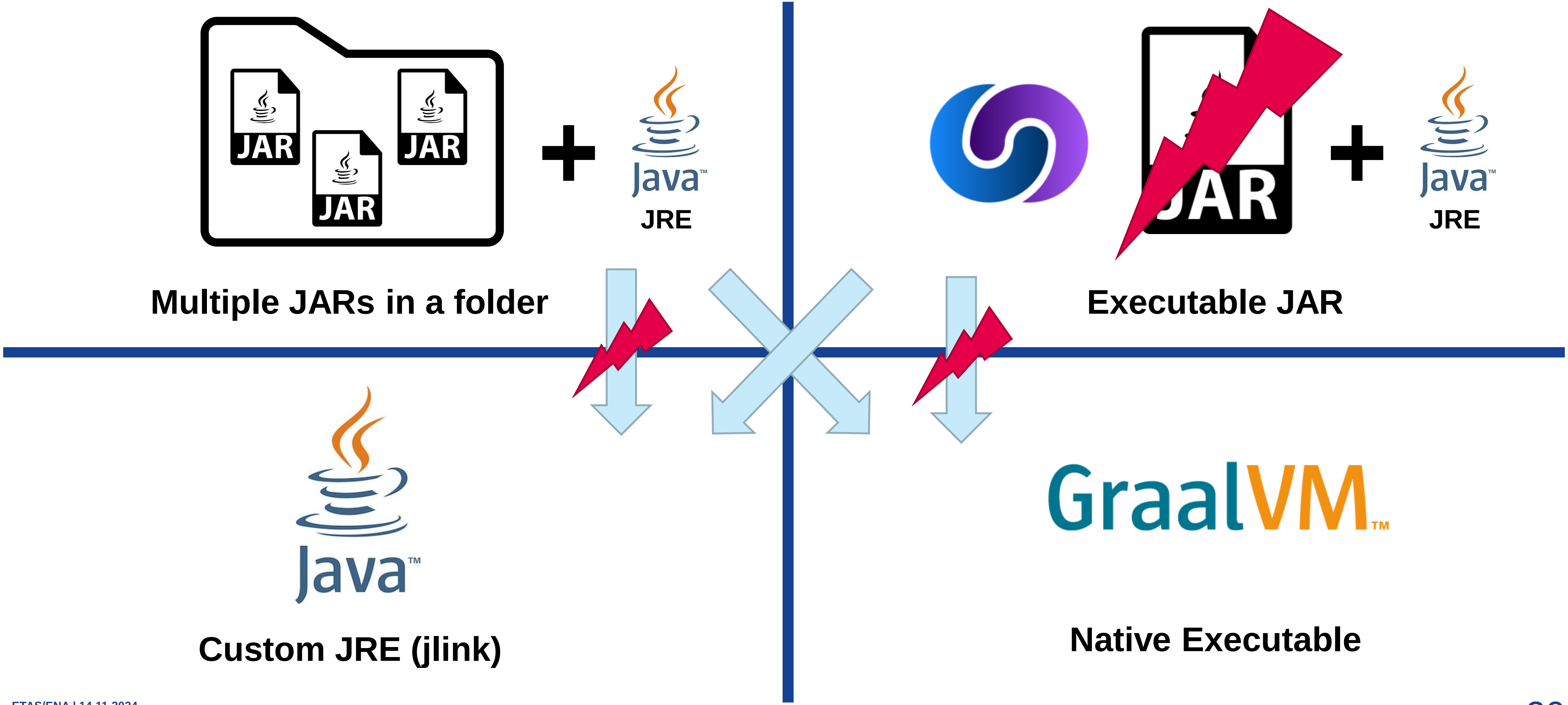
Deployment Variants

OSGi Connect / Apache Felix Atomos



Multiple JARs in a folder

Executable JAR

Custom JRE (jlink)

Native Executable

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Deployment Variants

Deployment (plain OSGi)
Multiple JARs in folder
Executable JAR
Custom JRE (jlink)
~~GraalVM Native Image~~

Deployment (OSGi Connect)
Multiple JARs in folder
~~Executable JAR~~
Custom JRE (jlink)
GraalVM Native Image

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Container

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Container

“Size matters” – Find the right base image

Alpine vs. Debian vs. Ubuntu

Image	Size
alpine:3	7.8 MB
debian:bullseye-slim	80.7 MB
ubuntu:jammy	77.9 MB

Eclipse Temurin vs. IBM Semeru

JDK vs. JRE

Image	Size (11)	Size (17)	Size (21)
eclipse-temurin:xx-jdk-jammy	~ 400 MB	~ 413 MB	~ 441 MB
eclipse-temurin:xx-jdk-alpine	~ 310 MB	~ 336 MB	~ 365 MB
eclipse-temurin:xx-jre-jammy	~ 262 MB	~ 261 MB	~ 285 MB
eclipse-temurin:xx-jre-alpine	**~ 175 MB**	**~ 185 MB**	**~ 210 MB**
ibm-semeru-runtimes:open-xx-jdk-jammy	~ 486 MB	~ 493 MB	~ 518 MB
ibm-semeru-runtimes:open-xx-jre-jammy	~ 281 MB	~ 283 MB	~ 301 MB
** icr.io/appcafe/ibm-semeru-runtimes: open-xx-jre-ubi-minimal	~ 289 MB	~ 291 MB	~ 342 MB

** images pulled on 2024/11/14*

*** RedHat Universal Base Image (UBI)*

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Container

Interlude: Distroless

- *"Distroless" images contain only your application and its runtime dependencies. They do not contain package managers, shells or any other programs you would expect to find in a standard Linux distribution.*

Image		Size
gcr.io/distroless/static-debian12	minimal Linux for "mostly-statically compiled" languages that do not require libc	1.98 MB
gcr.io/distroless/base-debian12	minimal Linux, glibc-based system	20.68 MB
gcr.io/distroless/java17-debian12	base image plus OpenJDK 17 and its dependencies	225.66 MB

- Distroless Java image is based on Debian and glibc, therefore bigger than an Alpine Temurin image
- Can be interesting in production for security reasons, but not for size

https://github.com/GoogleContainerTools/distroless

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Container

Interlude: Chiselled Ubuntu images

- *Chiselled Ubuntu is Canonical's take on* ***Distroless container images*** *built using the supported packages from the Ubuntu distribution.*

- Google is using Bazel as build tool for creating Distroless container images
- Canonical provides tools that are (probably) easier to use
  - **Rockcraft** – Tool to create OCI images https://github.com/canonical/rockcraft
  - **Chisel** – Tool for carving and cutting Debian packages https://github.com/canonical/chisel

- Ubuntu is based on Debian, therefore bigger than an Alpine Temurin image
- Can be interesting in production for security reasons, but not for size

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Container

Java Best Practices

- Install only what you need
  - Use JRE instead of JDK
  - Use multi-stage builds (e.g. to create JRE or Native Image)

- Don’t run Java apps as root

- Properly shutdown and handle events to terminate a Java application

- Take care of “container-awareness”

https://snyk.io/blog/best-practices-to-build-java-containers-with-docker/
https://developers.redhat.com/articles/2022/04/19/java-17-whats-new-openjdks-container-awareness#
https://blog.openj9.org/2021/06/15/innovations-for-java-running-in-containers/

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Container

Building Docker Images

– Use dedicated Docker files instead of generation tools

– Integrate image creation as part of the build via **`fabric8io/docker-maven-plugin`**
Maven/Gradle first

https://github.com/fabric8io/docker-maven-plugin
http://dmp.fabric8.io/

```
<plugin>
  <groupId>io.fabric8</groupId>
  <artifactId>docker-maven-plugin</artifactId>
  <extensions>true</extensions>
  <configuration>
    <images>  …  </images>
  </configuration>
  <executions>  …  </executions>
</plugin>
```

– **Jib** as an alternative to **`docker-maven-plugin`**
https://github.com/GoogleContainerTools/jib

– Use multi-stage build to checkout sources and build in one container, then create new production container with build result only
Docker first

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Container

Deployment Variant – Base Image – Image Size

Deployment (plain OSGi)	Base Image	Size
Multiple JARs in folder	eclipse-temurin:17-jre-alpine	~ 169 MB
Executable JAR	eclipse-temurin:17-jre-alpine	~ 170 MB
Custom JRE (jlink)	alpine:3	~ 78 MB
Custom JRE (jlink/compressed)	alpine:3	~ 56 MB

Deployment (OSGi Connect)	Base Image	Size
Multiple JARs in folder	eclipse-temurin:17-jre-alpine	~ 169 MB
Custom JRE (jlink)	alpine:3	~ 78 MB
Custom JRE (jlink/compressed)	alpine:3	~ 56 MB
GraalVM Native Image	scratch alpine:3	~ 38 MB ~ 43 MB

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Benchmark

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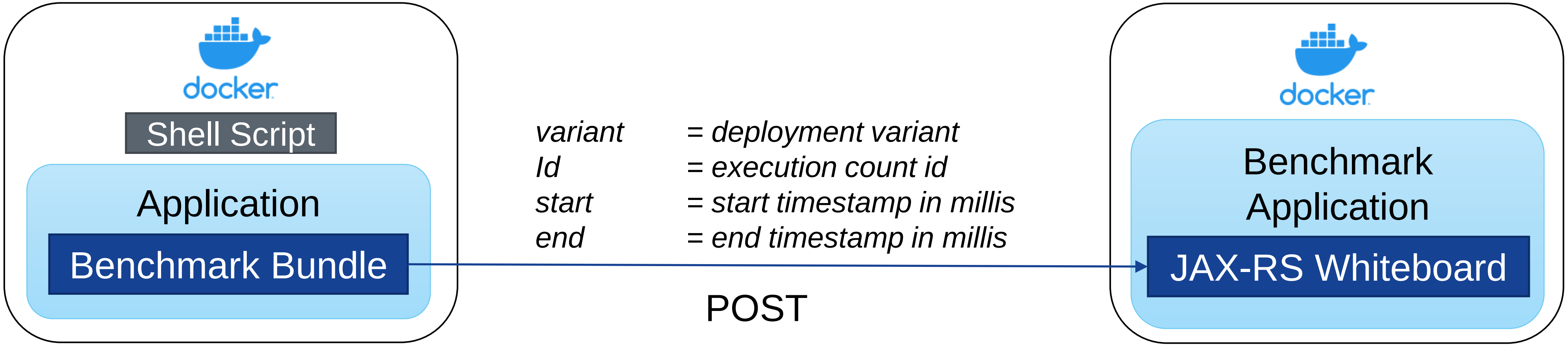
Benchmark



variant = deployment variant
Id = execution count id
start = start timestamp in millis
end = end timestamp in millis

Benchmark Bundle / Immediate Component

- Get start timestamp from system property
- Get current timestamp
- Send POST request via `java.net.http.HttpClient`
- Shutdown

Shell script

- Execute application multiple times in for-loop (clean/cache)
- Pass start timestamp as system property

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Benchmark Images Java 17

Deployment Variant – Base Image – Image Size – Benchmark Image Size

Deployment (plain OSGi)	Base Image	Size	Size Benchmark
Multiple JARs in folder	eclipse-temurin:17-jre-alpine	~ 169 MB	~ 171 MB
Executable JAR	eclipse-temurin:17-jre-alpine	~ 170 MB	~ 172 MB
Custom JRE (jlink)	alpine:3	~ 78 MB	~ 81 MB
Custom JRE (jlink/compressed)	alpine:3	~ 56 MB	~ 58 MB

Deployment (OSGi Connect)	Base Image	Size	Size Benchmark
Multiple JARs in folder	eclipse-temurin:17-jre-alpine	~ 169 MB	~ 171 MB
Custom JRE (jlink)	alpine:3	~ 78 MB	~ 81 MB
Custom JRE (jlink/compressed)	alpine:3	~ 56 MB	~ 58 MB
Oracle GraalVM 17 Native Image	scratch alpine:3	~ 47 MB (~ 52 MB)	(~ 58 MB) ~ 65 MB
GraalVM CE 17 Native Image	scratch alpine:3	~ 41 MB (~ 46 MB)	(~ 50 MB) ~ 58 MB

- + `coreutils` nanosecond support
- + `benchmark` bundle
- + `java.net.http` module
- + shell script support

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Benchmark Images

Deployment Variant – Base Image – Benchmark Image Size

Deployment (plain OSGi)	Base Image	Size (11)	Size (17)	Size (21)
Multiple JARs in folder	eclipse-temurin:xx-jre-alpine	~ 159 MB	~ 171 MB	~ 194 MB
Executable JAR	eclipse-temurin:xx-jre-alpine	~ 160 MB	~ 172 MB	~ 195 MB
Custom JRE (jlink)	alpine:3	~ 79 MB	~ 81 MB	~ 87 MB
Custom JRE (jlink/compressed)	alpine:3	~ 57 MB	~ 58 MB	~ 62 MB

Deployment (OSGi Connect)	Base Image	Size	Size (17)	Size (21)
Multiple JARs in folder	eclipse-temurin:21-jre-alpine	~ 159 MB	~ 171 MB	~ 194 MB
Custom JRE (jlink)	alpine:3	~ 79 MB	~ 81 MB	~ 87 MB
Custom JRE (jlink/compressed)	alpine:3	~ 57 MB	~ 58 MB	~ 62 MB
Oracle GraalVM xx Native Image	scratch alpine:3		(~ 58 MB) ~ 65 MB	(~ 57 MB) ~ 64 MB
GraalVM CE xx Native Image	scratch alpine:3		(~ 50 MB) ~ 58 MB	(~ 53 MB) ~ 60 MB

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Benchmark Results

	Java 11		Java 17		Java 21	
Deployment (plain OSGi)	**Startup Clean**	**Startup Cache**	**Startup Clean**	**Startup Cache**	**Startup Clean**	**Startup Cache**
Multiple JARs in folder	~ 1136 ms	~ 1070 ms	~ 984 ms	~ 1019 ms	~ 920 ms	~ 1023 ms
Executable JAR	~ 1208 ms	~ 1187 ms	~ 1086 ms	~ 1149 ms	~ 1073 ms	~ 1112 ms
Custom JRE (jlink)	~ 1387 ms	~ 1433 ms	~ 1425 ms	~ 1409 ms	~ 1315 ms	~ 1355 ms
Custom JRE (jlink/compressed)	~ 1589 ms	~ 1556 ms	~ 1511 ms	~ 1489 ms	~ 1455 ms	~ 1464 ms
Deployment (OSGi Connect)	**Startup Clean**	**Startup Cache**	**Startup Clean**	**Startup Cache**	**Startup Clean**	**Startup Cache**
Multiple JARs in folder classpath modulepath	~ 1611 ms ~ 1494 ms	~ 1098 ms ~ 1163 ms	~ 1479 ms ~ 1450 ms	~ 960 ms ~ 1072 ms	~ 1275 ms ~ 1204 ms	~ 988 ms ~ 1020 ms
Custom JRE (jlink)	~ 1411 ms	~ 1436 ms	~ 1394 ms	~ 1350 ms	~ 1293 ms	~ 1308 ms
Custom JRE (jlink/compressed)	~ 1598 ms	~ 1556 ms	~ 1526 ms	~ 1528 ms	~ 1441 ms	~ 1442 ms
Oracle GraalVM Native Image			- ~ 52 ms	- ~ 45 ms	- ~ 49 ms	- ~ 29 ms
GraalVM CE Native Image			- ~ 58 ms	- ~ 63 ms	- ~ 62 ms	- ~ 38 ms

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Conclusion

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Conclusion

- All Java deployment variants possible for OSGi applications via
  - Bndtools JPMS support
  - OSGi Connect (Felix Atomos)

- Different deployment variants have different startup & runtime behaviors
  Consider JIT vs. AOT compilation

- Newer Java versions have bigger container sizes

- Make decision about variant dependent on the use case,
  e.g. short running executables in container vs. long running application servers

- Further optimizations possible by configuring the Java runtime,
  e.g. Container-awareness, Garbage Collection, *Checkpoint & Restore*, etc.

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Appendix

OpenJ9 – CRIU – CRaC

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IBM Semeru / OpenJ9

Startup Performance

					-Xquickstart		-Xshareclasses		
Deployment (plain OSGi)	**Base Image**	**Size**	**Startup Clean**	**Startup Cache**	**Startup Clean**	**Startup Cache**	**Size**	**Startup Clean**	**Startup Cache**
Multiple JARs in folder	open-17-jre-jammy	~ 278 MB	~ 1101 ms	~ 1017 ms	~ 1052 ms	~ 1022 ms	~ 299 MB	~ 721 ms	~ 641 ms
Executable JAR	open-17-jre-jammy	~ 279 MB	~ 1288 ms	~ 1200 ms	~ 1222 ms	~ 1198 ms	~ 301 MB	~ 1004 ms	~ 1010 ms
Custom JRE (jlink)	debian:bullseye-slim	~ 166 MB	~ 2591 ms	~ 2604 ms	~ 1656 ms	~ 1645 ms	~ 189 MB	~ 1083 ms	~ 1098 ms
Custom JRE (jlink/compressed)	debian:bullseye-slim	~ 143 MB	~ 2748 ms	~ 2777 ms	~ 1777 ms	~ 1794 ms	~ 166 MB	~ 1177 ms	~ 1200 ms

Deployment (OSGi Connect)	**Base Image**	**Size**	**Startup Clean**	**Startup Cache**	**Startup Clean**	**Startup Cache**	**Size**	**Startup Clean**	**Startup Cache**
Multiple JARs in folder classpath modulepath	open-17-jre-jammy	~ 278 MB	 ~ 1041 ms ~ 1126 ms	 ~1039 ms ~ 1124 ms	 ~ 1016 ms ~ 1097 ms	 ~1021 ms ~ 1108 ms	~302 MB	 ~ 734 ms ~ 831 ms	 ~750 ms ~ 801 ms
Custom JRE (jlink)	debian:bullseye-slim	~ 166 MB	~2492 ms	~2562 ms	~1603 ms	~1630 ms	~190 MB	~1110 ms	~1180 ms
Custom JRE (jlink/compressed)	debian:bullseye-slim	~ 143 MB	~ 3309 ms	~2714 ms	~ 1714 ms	~1725 ms	~167 MB	~ 1170 ms	~1224 ms

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Checkpoint/Restore in Userspace (CRIU)

"AOT like startup performance with JIT runtime performance and behaviour"

- **CRaC (Coordinated Restore at Checkpoint)**
  - OpenJDK CRaC JDK
  - Azul Zulu JDK with CRaC support

- **OpenJ9 CRIU support**
  - IBM Semeru (OpenJDK/OpenJ9)

Further detailed information in:

CRaCin` your Java application - start so fast I want to CRIU

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Benchmark Sources

https://github.com/fipro78/osgi_deployment_options

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Thank you

Dirk Fauth

ETAS/ENA

dirk.fauth@etas.com